Update of the Unitarity Triangle Analysis

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We present the status of the Unitarity Triangle Analysis (UTA), within the Standard Model (SM) and beyond, with experimental and theoretical inputs updated for the ICHEP 2010 conference . Within the SM, we find that the general consistency among all the constraints leaves space only to some tension (between the UTA prediction and the experimental measurement) in $\text{BR}(B \to \tau \nu)$, $\sin 2\beta$ and ε_K. In the UTA beyond the SM, we allow for New Physics (NP) effects in $\Delta F = 2$ processes. The hint of NP at the 2.9σ level in the B_s-$\bar{B}_s$ mixing turns out to be confirmed by the present update, which includes the new D0 result on the dimuon charge asymmetry but not the new CDF measurement of ϕ_s, being the likelihood not yet released.

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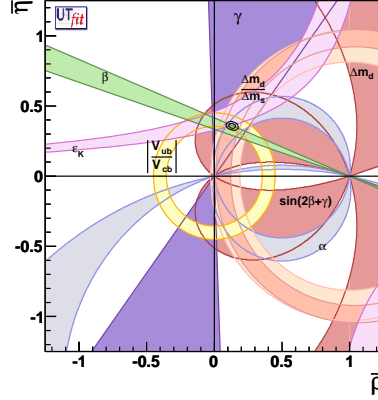
Figure 1: Results of the UTA within the SM. The contours display the selected 68% and 95% probability regions in the $(\bar{\rho}, \bar{\eta})$-plane. The 95% probability regions selected by the single constraints are also shown.

We present an update of the Unitarity Triangle Analysis (UTA) performed by the UTfit collaboration following the method described in refs. [1, 2]. Within the Standard Model (SM), we have included in ε_K the contributions of ξ and $\phi_\varepsilon \neq \pi/4$ which, as pointed out in [3], decrease the SM prediction for ε_K by $\sim 8\%$. We have also included the long-distance contribution calculated more recently in [4], which softens the 8% reduction to 6%. In a new paper [5] the perturbative calculation of the NNLO QCD corrections to the box diagram involving a top and a charm quark has been computed. This contribution, which is found to increase the theoretical prediction of ε_K by 3%, is not yet included in the UTA.

We observe, as main result of the UTA, that the CKM matrix turns out to be consistently overconstraint and the CKM parameters $\bar{\rho}$ and $\bar{\eta}$ are accurately determined: $\bar{\rho} = 0.132 \pm 0.020$, $\bar{\eta} = 0.358 \pm 0.012$ [6]. The UTA has thus established that the CKM matrix is the dominant source of flavour mixing and CP-violation and that New Physics (NP) effects can at most represent a small correction to this picture. We note, however, that the new contributions in ε_K generate some tension in particular between the constraints provided by the experimental measurements of ε_K and $\sin 2\beta$ (see fig. 1). As a consequence, the indirect determination of $\sin 2\beta$ turns out to be larger than the experimental value by $\sim 2.6\sigma$. We observe that the updated lattice average of the bag-parameter B_K [7] further enhances this ε_K-$\sin 2\beta$ tension. This is due to the fact that new unquenched results, though compatible with older quenched results, tend to lie below them.

Recently, we have shown [8] how to use the UTA to improve the prediction of $\mathrm{BR}(B \to \tau\nu)$ in the SM, thanks to a better determination of $|V_{ub}|$ and f_B. Within the SM the UTA prediction for $\mathrm{BR}(B \to \tau\nu)$ is found to deviate from the experimental measurement [9] by $\sim 3.2\sigma$. Even allowing for minimal flavour violating NP effects, a $\sim 3.0\sigma$ deviation from the experimental value is found. Moreover, it is interesting to note that a large value of $|V_{ub}|$ (which is closer to some inclusive determinations) would reduce this deviation but it would enhance the tension in $\sin 2\beta$.

We now present the update of the NP UTA, that is the UTA generalized to include possible NP effects. This analysis consists first in generalizing the relations among the experimental observ-

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ables and the elements of the CKM matrix, introducing effective model-independent parameters that quantify the deviation of the experimental results from the SM expectations. The possible NP effects considered in the analysis are those entering neutral meson mixing. Thanks to recent experimental developments, in fact, these $\Delta F = 2$ processes turn out to provide stringent constraints on possible NP contributions. In the case of $B_{d,s}$-$\bar{B}_{d,s}$ mixing, a complex effective parameter is introduced, defined as

$$C_{B_{d,s}} e^{2i\phi_{B_{d,s}}} = \frac{\langle B_{d,s}|H_{eff}^{full}|\bar{B}_{d,s}\rangle}{\langle B_{d,s}|H_{eff}^{SM}|\bar{B}_{d,s}\rangle},\tag{1}$$

being H_{eff}^{SM} the SM $\Delta F = 2$ effective Hamiltonian and H_{eff}^{full} its extension in a general NP model, and with $C_{B_{d,s}} = 1$ and $\phi_{B_{d,s}} = 0$ within the SM. All the mixing observables are then expressed as a function of these parameters and the SM ones (see refs. [10, 11, 12] for details). In a similar way, for the K-$\bar{K}$ system, one can write

$$C_{\varepsilon_K} = \frac{Im[\langle K|H_{eff}^{full}|\bar{K}\rangle]}{Im[\langle K|H_{eff}^{SM}|\bar{K}\rangle]}, \qquad\qquad C_{\Delta m_K} = \frac{Re[\langle K|H_{eff}^{full}|\bar{K}\rangle]}{Re[\langle K|H_{eff}^{SM}|\bar{K}\rangle]},\tag{2}$$

with $C_{\varepsilon_K} = C_{\Delta m_K} = 1$ within the SM.

In this way, the combined fit of all the experimental observables selects a region of the $(\bar{\rho}, \bar{\eta})$ plane ($\bar{\rho} = 0.135 \pm 0.040$, $\bar{\eta} = 0.374 \pm 0.026$) which is consistent with the results of the SM analysis, and it also constraints the effective NP parameters.

For K-$\bar{K}$ mixing, the NP parameters are found in agreement with the SM expectations. In the B_d system, the mixing phase ϕ_{B_d} is found $\simeq 1.8\sigma$ away from the SM expectation, reflecting the tension in $\sin 2\beta$ discussed above.

The B_s-meson sector, where the tiny SM mixing phase $\sin 2\beta_s \simeq 0.041(4)$ could be highly sensitive to a NP contribution, represents a privileged environment to search for NP. In this sector, an important experimental progress has been achieved at the Tevatron collider since 2008 when both the CDF [13] and D0 [14] collaborations published the two-dimensional likelihood ratio for the width difference $\Delta\Gamma_s$ and the phase $\phi_s = 2(\beta_s - \phi_{B_s})$, from the tagged time-dependent angular analysis of the decay $B_s \to J_\psi \phi$.

In 2009 the update of the UTfit analysis of ref. [15], combining the CDF and D0 results including the D0 two-dimensional likelihood without assumptions on the strong phases, yielded $\phi_{B_s} = (-69 \pm 7)^\circ \cup (-19 \pm 8)^\circ$, which is 2.9σ away from the SM expectation $\phi_{B_s} = 0$.

In 2010 two surprising news have arrived from the CDF and D0 experiments. On the one hand the new CDF measurement [16] based on an enlarged (5.2 fb^{-1}) data sample has provided a reduced significance of the deviation, from 1.8σ to $\simeq 1\sigma$. On the other hand D0 has performed a new measurement of the dimuon charge asymmetry $a_{\mu\mu}$ [17], which points to a large value of ϕ_{B_s}, but also to a value for the width difference $\Delta\Gamma_s$ that is significantly larger than the SM prediction. If confirmed, the latter result would lead to one of the two (unlikely) explanations: either a huge NP contribution shows up in the tree-level observable $\Delta\Gamma_s$ or the operator product expansion badly fails (while it turns out to work well in describing b-hadron lifetimes where the same theoretical approach is adopted for the diagonal matrix element Γ_{11} instead of Γ_{12}).

It will be interesting to see if these CDF and D0 results will be confirmed once the Tevatron measurements will improve. At the moment the new CDF result is not included in the analysis
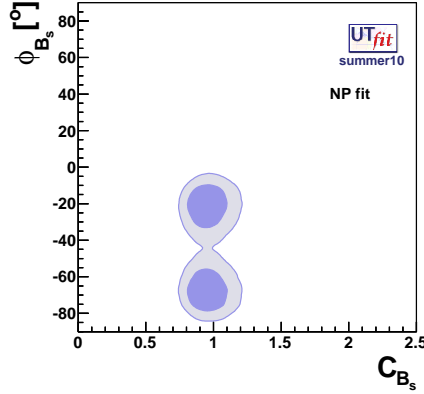
Figure 2: 68% (dark) and 95% (light) probability regions in the (C_{B_s}, ϕ_{B_s})-plane.

since the $\Delta\Gamma_s$-ϕ_s likelihood has not been released yet. Including the D0 result for $a_{\mu\mu}$, we find $\phi_{B_s} = (-68 \pm 8)° \cup (-20 \pm 8)°$, which confirms the 2.9σ deviation from the SM expectation $\phi_{B_s} = 0$ (see fig. 2).

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